

N80 24769

A CELLULAR GLASS SUBSTRATE SOLAR CONCENTRATOR

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ABSTRACT

Acurex Corporation, under contract to the Jet Propulsion Laboratory, is developing a second generation point focusing solar concentrator. The design is based on reflective gores fabricated of thin glass mirror bonded continuously to a contoured substrate of cellular glass.

To date the preliminary design effort is complete and is reviewed in this presentation. The concentrator aperture and structural stiffness has been optimized for minimum concentrator cost given the performance requirement of delivering 56 kW_{th} to a 22 cm (8.7 in) diameter receiver aperture with a direct normal insolation of 845 watts/m² and an operating wind of 50 kmph (31 mph). The reflective panel, support structure, drives, foundation and instrumentation and control subsystem designs, optimized for minimum cost, are summarized. The use of cellular glass as a reflective panel substrate material is shown to offer significant weight and cost advantages compared to existing technology materials. Lastly, a design summary and key results are presented.

INTRODUCTION

Acurex Corporation, under contract to the Jet Propulsion Laboratory, is developing a second generation point focusing solar concentrator. The scope of this project currently encompasses three tasks, namely:

1. Preliminary design of a cellular glass substrate advanced solar concentrator
2. Detail design of reflective gore panels
3. Mass production cost assessment

The overall objective of this project is to develop a minimum cost per kilowatt solar concentrator design within the constraints of 1985 mass production technology. As the thermal output of the concentrator has been specified, this goal can be expressed in terms of \$/m² of aperture area. An installed cost of \$70 to 100/m² in 1978 dollars is the target.

The key element of the second generation concentrator design is the light weight, self-supporting reflective panel made possible by the use of cellular glass as a reflective mirror substrate material. The effect of the low weight of the panels cascades down through the other concentrator subsystems. A light-weight, self-supporting panel allows the design of a

light-weight supporting structure, which in turn, yields low drive and foundation loads and low installation labor which all leads to a low cost concentrator design. Cellular glass is a desirable reflector substrate material because of its high stiffness to weight ratio, thermal expansion match to mirror glass and environmental durability. It is a low cost material, selling for approximately \$0.30 per board-foot in large volume production in the self-supported insulation market.

DESIGN DESCRIPTION

The design of the cellular glass substrate concentrator is shown in Figure 1. The concentrator is an 10.9 meter diameter, two-axis tracking, parabolic dish solar concentrator. The reflective surface of this design consists of inner and outer groups of mirror glass/cellular glass gores. The gores are attached as simply supported overhang beams to a ring truss support structure to form a complete but physically discontinuous reflective surface. There are five structural support subsystems; the gore support a quadripod receiver support, a counterweight support, a tripod center pedestal and a tilted pyramid drive structure. Elevation motion is produced by a ball screw and azimuth motion by a chain and sprocket perimeter drive. The foundation consists of concrete piers for the center pedestal and a raised steel track also on concrete piers.

The reflective panel or gore design is a sandwiched mirror glass/cellular glass/unsilvered glass configuration. The mirror glass is backsilvered 0.040 thickness Corning 7809 aluminoborosilicate fusion glass. The cellular glass is 12 lb/ft³ Pitt-Corning Foamsil®75 and is specifically tailored to match the coefficient of thermal expansion of the 7809 mirror glass. The backsheet is an unsilvered piece of 0.040 thickness Corning 7809 glass. The sandwich configuration was selected as the design which resulted in the minimum weight gore. The concentrator design consists of 40 outer gores and 24 inner gores. The maximum gore width was limited by the allowable membrane stress for a single panel per gore. Gore weights, less the attachments, are 49 and 32 lbs for the outer and inner rings, respectively.

The support structure design features welded steel shop subassembly construction using standard size, commercially available, structural steel members. Finite element analysis techniques were used to optimize the support structure for minimum weight. The concentrator design has a total structural steel weight of 4,335 lbs and a concrete counterweight of 10,000 lbs.

The drive design features positive traction, rugged, state-of-the-art components. Approximately 100 different combinations of drive power, actuation mechanism, and drive and foundation structure alternatives were evaluated. Life cycle costs were developed for each of the alternative concepts. Chain/sprocket and cable/drum azimuth drives were found to provide essentially equivalent minimum life cycle costs. The chain sprocket design was selected because of its greater stiffness over a cable/drum design. A ball screw was selected as the minimum life cycle cost elevation drive

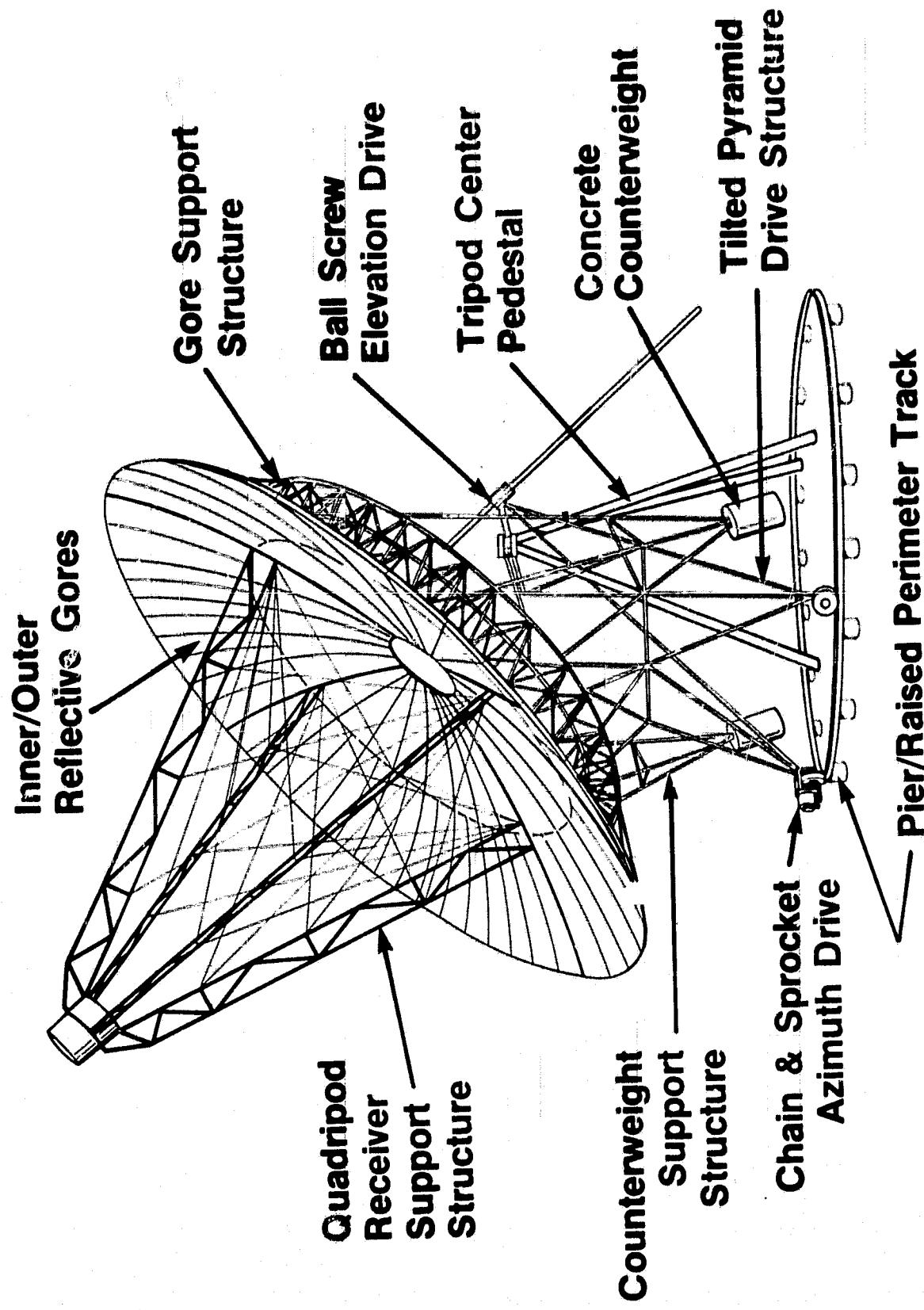


Figure 1. Design description.

design. Due to the requirement for failsafe stowing capability, electric motors and a fossil fuel generator were selected for drive motors and emergency power respectively under the assumption that a single generator set would provide power to at least four concentrators in a multi-unit field.

The foundation design features simple installation and adaptability to sloping or rough terrain. The foundation consists of a tubular steel tripod pedestal which supports the azimuth bearing and a raised steel track upon which the drive structure rides. Both the pedestal and track are anchored to simple drilled and poured concrete piers. The pedestal angle and number of piers were optimized for minimum cost.

The electrical subsystem consists of off-the-shelf components providing for power distribution and lightning and grounding protection. The instrumentation and control subsystem consists of the tracker control and shaft encoders. A hybrid, two-axis, image tracking system is recommended. Coarse synthetic tracking will be achieved through a microcomputer based control system. Accurate active tracking will be achieved by a two-axis photodetector located at the focal plane and sensing the position of the reflected image. Image sensing not only provides inherent gravity compensation but also compensates for steady-state wind deflections.

KEY RESULTS

The key results of the project, through the preliminary design phase, are as follows:

- Optimized Concentrator Diameter = 10.9 meters
The concentrator aperture diameter and structural stiffness have been optimized given the performance requirement of delivering 56 KW_{th} to a 22 cm (8.7 inch) diameter receiver aperture with a direct normal insolation of 845 watts/m² and an operating wind of 50 kmph (31 mph).
- Developed Minimum Weight Preliminary Design
Extensive design/analysis efforts have produced a minimum weight concentrator design. In mass production, a minimum weight design, based on low-cost materials, will provide a minimum cost design. The use of cellular glass as a reflective panel substrate material offers significant weight advantages compared to alternate substrate materials
- Preliminary Cost Estimate = \$87/m² Installed
Cost estimates made from vendor contacts and rule-of-thumb cost per pound guidelines indicate that a cellular glass substrate concentrator meets the JPL cost target on a dollar per unit aperture area basis.

- Projected Future Cost Reduction = 5 to 10 Percent
A cost reduction of 5 to 10 percent is anticipated as a result of detailed production planning and weight reductions achieved in detail design.

- Recommended Cellular Glass Reflective Panel Technology Development

The use of cellular glass as the structural support for glass mirrors is not state-of-the-art technology. As such, a development effort is required. Acurex has recommended a specific program leading to the test demonstration of fullsize engineering gores. This effort consists of bonding and grinding studies, subscale gore fabrication and optical, structural and environmental testing and fullscale engineering demonstration.